CHAPTER 11

PACIFIC OCEAN PERCH

by

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Executive Summary

The following changes were made to the Pacific Ocean Perch (POP) assessment relative to the November 2001 SAFE:

Changes in the Input Data

(1) The 2001 harvest level have been revised and harvests through September 7, 2002 have been included in the assessment.

(2) The 2001 age compositions from the Aleutian Islands (AI) fishery was included in the assessment.

(3) The biomass estimate and length composition from the 2002 AI survey were included in the assessment.

Changes in the Assessment Results

(1) A summary of the 2002 assessment recommended ABC's relative to the 2001 recommendations is as follows:

	Assessment Year	
	2001	2002
ABC	14,776 t	15,071 t
OFL	17,510 t	17,856 t

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INTRODUCTION

Pacific ocean perch (*Sebastes alutus*) inhabit the outer continental shelf and upper slope regions of the North Pacific Ocean and Bering Sea. Pacific ocean perch, and four other associated species of rockfish (northern rockfish, *S. polyspinis*; rougheye rockfish, *S. aleutianus*; shortraker rockfish, *S. borealis*; and sharpchin rockfish, *S. zacentrus*) were managed as a complex in the two distinct areas from 1979 to 1990. Known as the POP complex, these five species were managed as a single entity with a single TAC (total allowable catch). In 1991, the North Pacific Fishery Management Council separated POP from the other red rockfish in order to provide protection from possible overfishing. Of the five species in the former POP complex, *S. alutus* has historically been the most abundant rockfish in this region and has contributed most to the commercial rockfish catch. Furthermore, the bulk of the research on rockfish has been concentrated on *S. alutus*; relatively little biological or assessment information is available for the other rockfish species. This chapter discusses strictly Pacific ocean perch; the assessment of other red rockfish is addressed in another chapter.

Since 2001, POP in the Bering Sea-Aleutian Islands area have been assessed and managed as a single stock. Motivations for this change includes the paucity of data in the EBS upon which to base an age-structured assessment, and uncertainty that the EBS POP represent a discrete stock (Spencer and Ianelli 2001).

FISHERY

Pacific ocean perch were highly sought by Japanese and Soviet fisheries and supported a major trawl fishery throughout the 1960s. Catches in the eastern Bering Sea peaked at 47,000 (metric tons, t) in 1961; the peak catch in the Aleutian Islands region occurred in 1965 at 109,100 t. Apparently, these stocks were not productive enough to support such large removals. Catches continued to decline throughout the 1960s and 1970s, reaching their lowest levels in the mid 1980s. With the gradual phase-out of the foreign fishery in the 200-mile U.S. Exclusive Economic Zone (EEZ), a small joint-venture fishery developed but was soon replaced by a domestic fishery by 1990. In 1990 the domestic fishery recorded the highest Pacific ocean perch removals since 1977. The history of *S. alutus* landings since implementation of the Magnuson Fishery Conservation and Management Act (MFCMA) is shown in Table 1.

Estimates of retained and discarded Pacific ocean perch from the fishery have been available since 1990 (Table 2). The eastern Bering Sea region generally shows a higher discard rate than in the Aleutian Islands region. For the period from 1990 to 2000, the Pacific ocean perch discard rate in the eastern Bering Sea averaged about 29.1%, and the 2001 discard rate was 55%. In contrast, the discard rate from 1990 to 2000 in the Aleutian Islands averaged about 16%. The removals from trawl and hydoracoustic surveys are shown in Table 3.

There has been little change in the distribution of observed Aleutian Islands POP catch from the foreign and joint venture fisheries (years 1977-1988) and the domestic fishery (years 1990-2001) with respect to fishing depth and management area. The fishing depth accounting for the largest proportion of catch in each fishery was 200-299 m, with 49% and 66% of the observed foreign/joint venture and domestic catch, respectively (Table 4). Management area 541 contributes the largest share of the observed catch in each fishery; with 46% and 42% in the foreign/joint venture and domestic fisheries, respectively (Table 5). Note that this is in contrast to the year 2001 fishery, in which area 543 contributes the largest share of the catch. Area 543 contributed a large share of the catch in the late 1970s foreign fishery , as well as the domestic fishery from the mid-1990s to the present. In the late 1980s to the early

1990s, area 541 contributed a large share of the catch. Note that the proportions of total POP caught that were actually sampled by observers was very low in the foreign fishery, due to low sampling ratio prior to 1984 (Megrey and Wespestad 1990).

DATA

Fishery Data

Catch per unit effort (CPUE) data from Japanese trawl fisheries indicate that Pacific ocean perch stock abundance has declined to very low levels in the Aleutian Islands region (Ito 1986). By 1977, CPUE values had dropped by more than 90-95% from those of the early 1960s. Japanese CPUE data after 1977, however, is probably not a good index of stock abundance because most of the fishing effort has been directed to species other than Pacific ocean perch. Standardizing and partitioning total groundfish effort into effort directed solely toward Pacific ocean perch is extremely difficult. Increased quota restrictions, effort shifts to different target species, and rapid improvements in fishing technology undoubtedly affect our estimates of effective fishing effort. Consequently, we included CPUE data primarily to evaluate its consistency with other sources of information. We used nominal CPUE data for class 8 trawlers in the eastern Bering Sea and Aleutian Islands regions from 1968-1979. During this time period these vessels were known to target on Pacific ocean perch (Ito 1982).

Length measurements and otoliths read from the EBS and AI management areas were combined to create fishery age/size composition matrices (Table 6). In 1982, the method for aging otoliths at the Alaska Fisheries Science Center changed from surface reading to the break and burn method (Betty Goetz, Alaska Fisheries Science Center, pers. comm.), as the latter method is considered more accurate for older fish (Tagart 1984). The time at which the otoliths collected from 1977 to 1982 were read is not known for many vessels and cruises. However, the information available suggests that otoliths from 1977 to 1980 were read prior to 1981, whereas otoliths from 1981 and 1982 were read after 1982.

Survey Data

The Aleutian Islands survey biomass estimates were used as an index of abundance for the BSAI POP stock. Note that there is wide variability among survey estimates from the portion of the southern Bering Sea portion of the survey (from 165 W to 170 W), as the post-1991 coefficients of variation (CVs) range from 0.41 to 0.64 (Table 7). The biomass estimates in this region increased from 1,501 t in 1991 to 18,217 t in 1994; the 2002 estimate is 16,311 t. The estimated biomass of Pacific ocean perch in the Aleutian Islands management area region (170^{o} W to 170^{o} E) appears to be less variable, with CVs ranging from 0.16 to 0.24. For the entire survey area, there has been a steady increase from 1980 to 1997, followed by declines to the 2000 and 2002 estimates. The 1991 trawl survey produced a biomass estimate of 351,093 t, more than three times the 1980 point estimate. The 1994 and 1997 trawl surveys produced biomass estimates of 383,618 and 625,272 t. Since 1997, the trawl survey estimates declined from 511,706 t in 2000 and 468,588 t in 2002. Age composition data exists for each survey year except 2002. The length measurements and otoliths read from the Aleutian Islands surveys are shown in Table 8.

Historically, the Aleutian Island survey have indicated higher abundances in the western and central Aleutian Islands, and this pattern was repeated in the 2002 survey (Figure 1). In particular, areas near Stalemate Bank, Tahoma Bank-Buldir Island, and Kiska Island showed high CPUE in 2002 survey tows.

The 2002 EBS slope survey represents the initiation of a new biennial survey. The most recent slope survey prior to 2002, excluding some preliminary tows in 2000 intended for evaluating survey gear, was in 1991, and previous slope survey results have not been used in the BSAI model due to high CVs, relatively small population sizes compared to the AI biomass estimates, and lack of recent surveys. The 2002 EBS slope survey POP biomass estimate and its standard deviation were 76,685 t and 38,589 t, resulting in a CV of 0.53. A plot of the survey CPUE per haul reveals a large number of hauls with no catch mixed with few hauls with sizable catches, with one haul southwest of the Pribilof Islands having an especially large catch (Figure 2). The 2002 EBS slope survey results are not used in this assessment, and the feasibility of incorporating this time series will be evaluated in future years.

The following table summarizes the data available for the BSAI POP model:

Component	BSAI
Fishery catch	1960-2002
Fishery age composition	1977-82, 1990,1998,2000,2001
Fishery size composition	1964-72, 1983-1984,1987-1989,1991-1997,1999
Fishery CPUE	1968-79
Survey age composition	1980, 83, 86, 91, 94, 97, 2000
Survey size composition	2002
Survey biomass estimates	1980, 83, 86, 91, 94, 97, 2000, 2002

Biological Data

The surveys produce large numbers of samples for age determination, length-weight relationships, sex ratio information, and for estimating the length distribution of the population. The age compositions were determined by constructing age-length keys for each year and using them to convert the observed length frequencies from each year. Because the survey age data were based on the break and burn method of ageing Pacific ocean perch, they were treated as unbiased but measured with error. Kimura and Lyons (1991) give data on the percent agreement between otolith readers for Pacific ocean perch. The estimate of aging error was identical to that presented in Ianelli and Ito (1991). The assessment model uses this information to create a transition matrix to convert the simulated "true" age composition to a form consistent with the observed but imprecise age data.

Assessments of Pacific ocean perch have improved significantly because of improved methods of age determination. Historically, Pacific ocean perch age determinations were done using scales and surface readings from otoliths. These gave estimates of natural mortality of about 0.15 and longevity of about 30 years (Gunderson 1977). Based on the now accepted break and burn method of age determination using otoliths, Chilton and Beamish (1982) determined the maximum age of *S. alutus* to be 90 years. Using similar information, Archibald et al. (1981) concluded that natural mortality for Pacific ocean perch should be on the order of 0.05.

Aleutian Islands survey data from years 1980, 1983, 1986, 1991, 1994, and 1997, and eastern Bering Sea survey data from 1981, 1982, and 1991, were used to estimate von Bertalannfy growth curves. The resulting growth curves are:

	Aleutian Islands	Eastern Bering Sea
L_{inf}	40.09	40.38
K	0.1629	0.1323
t_0	0.72855	1.7766

There is little difference in the growth curves between areas, or in the estimated growth curves within an area over time. Growth information from the Aleutian Islands was used to convert estimated numbers at age within the model to estimated numbers at length.

The estimated length(cm)-weight(g) relationship for Aleutian Islands POP was estimated with survey information from the same years. For the eastern Bering Sea, fishery data from 1975 to 1999 were used to estimate the length-weight relationship, as individual weights were not recorded in the EBS surveys. The resulting length-weight relationships, where weight = a*(length)^b, were similar between regions:

	Aleutian Islands	Eastern Bering Sea
a	1.054×10^{-5}	8.59×10^{-6}
b	3.08	3.13

Again, there was little difference between areas, or between years in a single area. The Aleutian Islands length-weight relationship was used to produce estimated weights at age. A combined-sex model was used, as the ratio of males to females varied slightly from year to year but was not significantly different from 1:1 (Ianelli and Ito 1991). The proportion mature at age schedule used is identical to that used in the Gulf of Alaska POP assessment.

ANALYTIC APPROACH

Model Structure

An age-structured population dynamics model, implemented in the software program ADModelbuilder, was used to obtain estimates of recruitment, numbers at age, and catch at age. Population size in numbers at age a in year t was modeled as

$$N_{t,a} = N_{t-1,a-1}e^{-Z_{t-1,a-1}} \qquad 3 \le a < A, \quad 1960 \le t \le T$$

where Z is the sum of the instantaneous fishing mortality rate ($F_{t,a}$) and the natural mortality rate (M), A is the maximum number of age groups modeled in the population (defined as 25), and T is the terminal year of the analysis (defined as 2001). The numbers at age A are a “pooled” group consisting of fish of age A and older, and are estimated as

$$N_{t,A} = N_{t-1,A-1}e^{-Z_{t-1,A-1}} + N_{t-1,A}e^{-Z_{t-1,A}}$$

The numbers at age in the first year are estimated as

$$N_a = R_0 e^{-M(a-3)+\gamma_a}$$

where R_0 the number of age 3 recruits for an unfished population and γ is an age-dependant deviation assumed to be normally distributed with mean of zero and a standard deviation equal to the recruitment standard deviation (σ). The previous stock synthesis model estimated the first year numbers at age to be in equilibrium with an historical catch of 400 t, and required estimation of a historic fishing mortality rate parameter. The equilibrium assumption implied that the recruitment strengths of all cohorts in the first year were equivalent, whereas the estimation of the vector of age-dependant deviations from average recruitment allows estimation of year class strength.

The total numbers of age 3 fish from 1960 to 1994 are estimated as parameters in the model, and are modeled with a lognormal distribution

$$N_{t,3} = e^{(\mu_R + \nu_t)}$$

where ν is a time-variant deviation. The recruitments from 1995 to 2001 are set the median recruitment, e^{μ_r}.

The fishing mortality rate for a specific age and time ($F_{t,a}$) is modeled as the product of a fishery age-specific selectivity (*fishsel*) and a year-specific fully-selected fishing mortality rate *f*. The fully selected mortality rate is modeled as the product of a mean (μ_f) and a year-specific deviation (ϵ_t), thus $F_{t,a}$ is

$$F_{t,a} = fishsel_a * f_t \equiv fishsel_a * e^{(\mu_f + \varepsilon_t)}$$

Given the similarity between the two fisheries in terms of depth and management area fished (Tables 4 and 5), a single fishery selectivity curve was used. A double logistic fishery selectivity curve been used in some previous assessments, as an asymptotic selectivity pattern for the fishery was originally found to be inadequate in describing the observed data (Ianelli and Ito 1992). However, the resulting fishery selectivity curves in some assessments have shown sharp declines in over a small range of older ages, implying unusually large selectivity differences in fish of quite similar size and age. In this model, a series of selectivity curves were evaluated, including the asymptotic logistic curve, the dome-shaped double logistic, and a double logistic curve that penalizes sharp differences between adjacent ages.

The mean numbers at age for each year was computed as

$$\overline{N}_{t,a} = N_{t,a} * (1 - e^{-Z_{t,a}}) / Z_{t,a}$$

The predicted length composition data were calculated by multiplying the mean numbers at age by a transition matrix, which gives the proportion of each age (rows) in each length group (columns); the sum across each age is equal to one. Twenty-five length bins were used, ranging from 15 cm to 39+ cm. The transition matrix was based upon an estimated von Bertalanffy growth relationship, with the variation in length at age interpolated from between the first and terminal ages in the model.

Both unbiased and biased age distributions are used in the model. For unbiased age distributions, aging imprecision is inferred from studies indicating that the percent agreement between readers varies from 60% for age 3 fish to 13% for age 25 fish (Kimura and Lyons 1991). The information on percent agreement was used to derive the variability of observed age around the “true”age, assuming a normal distribution. The mean number of fish at age available to the survey or fishery is multiplied by the aging error matrix to produce the observed survey or fishery age compositions. Similarly, estimated biased age distributions are computed by multiplying the mean number of fish at age by a biased aging error matrix, which was derived from data in Tagart (1984).

Catch biomass at age was computed as the product of mean numbers at age, instantaneous fishing mortality, and weight at age. The predicted trawl survey biomass (*pred_biom*) was computed as

$$pred\_biom_t = qsurv \sum_a \left(\overline{N}_{t,a} * survsel_a * W_a \right)$$

where W_a is the population weight at age, $survsel_a$ is the survey selectivity, and *qsurv* is the trawl survey catchability. We use the Aleutian Islands trawl survey biomass estimates in a relative sense rather than in an absolute sense by allowing *qsurv* to be estimated in the model rather than fixed at 1.0. Similarly, the predicted catch per unit effort index was computed as

$$pred\_cpue_t = qcpue \sum_a \left(\overline{N}_{t,a} * fishsel_a * W_a \right)$$

where *qcpue* is the scaling factor for the CPUE index.

Parameters Estimated Independently

The parameters estimated independently include the biased and unbiased age error matrices, the age-length transition matrix, individual weight at age, and natural mortality. The age error matrices were obtained from information in Kimura and Lyons (1991) and Tagart (1984), and are identical to those used in the previous assessments. The age-length transition matrix was derived from the von Bertalanffy growth parameters discussed above, which were combined with the length-weight relationship to obtain estimates of individual weights. The natural mortality rate *M* was fixed at 0.05, consistent with studies on POP age determination (Chilton and Beamish 1982, Archibald et al. 1981).

Parameters Estimated Conditionally

Parameter estimation is facilitated by comparing the model output to several observed quantities, such as the age and length composition of the survey and fishery catch, the survey biomass, and the catch biomass. The general approach is to assume that deviations between model estimates and observed quantities are attributable to observation error and can be described with statistical distributions. Each data component provides a contribution to a total log-likelihood function, and parameter values that maximize the log-likelihood are selected.

The log-likelihood of the initial recruitments were modeled with a lognormal distribution

$$\lambda_1 \left[\sum_t \frac{\left(\nu_t + \frac{\sigma^2}{2} \right)^2}{2\sigma^2} + n \ln(\sigma) \right]$$

The adjustment of adding $\sigma^2/2$ to the deviation was made in order to produce deviations from the mean, rather than the median, recruitment.

The log-likelihoods of the fishery and survey age and length compositions were modeled with a multinomial distribution. The log of the multinomial function (excluding constant terms) for the fishery length composition data, with the addition of a term that scales the likelihood, is

$$n_{f,t,l}\sum_{s,t,l} p_{f,t,l}\ln(\hat{p}_{f,t,l}) - p_{f,t,l}\ln(p_{f,t,l})$$

where n is the square root of the number of fish measured, and $p_{f,t,l.}$ and $\hat{p}_{f,t,l}$ are the observed and estimated proportion at length in the fishery by year and length. The likelihood for the age and length proportions in the survey, $p_{surv,t,a}$ and $p_{surv,t,l}$, respectively, follow similar equations.

The log-likelihood of the survey biomass was modeled with a lognormal distribution:

$$\lambda_2\sum_t (\ln(obs\_biom_t) - \ln(pred\_biom_t))^2 / 2cv_t^{\,2}$$

where obs_biom_t is the observed survey biomass at time t, cv_t is the coefficient of variation of the survey biomass in year t, and λ_2 is a weighting factor. The log-likelihood of the CPUE index is computed in a similar manner, and is weighted by λ_3. The log-likelihood of the catch biomass was modeled with a lognormal distribution:

$$\lambda_4\sum_t (\ln(obs\_cat_t) - \ln(pred\_cat_t))^2$$

where obs_cat_t and $pred\_cat_t$ are the observed and predicted catch. Because the catch biomass is generally thought to be observed with higher precision that other variables, λ_4 is given a very high weight so as to fit the catch biomass nearly exactly. This can be accomplished by varying the F levels, and the deviations in F are not included in the overall likelihood function. The overall negative log-likelihood function is

$$\begin{aligned}
&\lambda_1\left(\sum_t\left(\frac{\nu_t+\sigma^2/2}{2\sigma^2}\right)^2 + n\ln(\sigma)\right) + \\
&\lambda_2\sum_t (\ln(obs_biom_t) - \ln(pred_biom_t))^2 / 2 * cv_t^2 + \\
&\lambda_3\sum_t (\ln(obs_cpue_t) - \ln(pred_cpue_t))^2 / 2 * cv_{CPUE}^2 + \\
&n_{f,t,l}\sum_{s,t,l} p_{f,t,l}\ln(\hat{p}_{f,t,l}) - p_{f,t,l}\ln(p_{f,t,l}) + \\
&n_{f,t,a}\sum_{s,t,l} p_{f,t,a}\ln(\hat{p}_{f,t,a}) - p_{f,t,a}\ln(p_{f,t,a}) + \\
&n_{surv,t,a}\sum_{s,t,a} p_{surv,t,a}\ln(\hat{p}_{surv,t,a}) - p_{surv,t,a}\ln(p_{surv,t,a}) + \\
&n_{surv,t,l}\sum_{s,t,a} p_{surv,t,l}\ln(\hat{p}_{surv,t,l}) - p_{surv,t,l}\ln(p_{surv,t,l}) + \\
&\lambda_4\sum_t (\ln(obs_cat_t) - \ln(pred_cat_t))^2
\end{aligned}$$

For the model run in this analysis, λ_1, λ_2, λ_3, and λ_4 were assigned weights of 1,1, 0.5, and 500, reflecting a de-emphasis of the CPUE index and strong emphasis on fitting the catch data. The sample sizes for the age and length compositions were set to the square root of the number of fish. The negative log-likelihood function was minimized by varying the following parameters (assuming a double logistic fishery selectivity curve):

Parameter type	Number
1) fishing mortality mean (μ_f)	1
2) fishing mortality deviations (ϵ_t)	43
3) recruitment mean (μ_r)	1
4) recruitment standard deviation (σ)	1
5) recruitment deviations (ν_t)	36
6) historic recruitment (R_0)	1
7) first year recruitment deviations	22
8) Biomass survey catchability	1
9) CPUE index catchability	1
10) fishery selectivity parameters	4
11) survey selectivity parameters	2
Total parameters	113

RESULTS

Model Selection

Three separate models were evaluated that differed with respect how the fishery selectivity curve was modeled. In Model 1, the fishery selectivity curve was modeled with the double logistic function, as in previous assessments:

$$fishsel_a = \frac{1}{(1+e^{-aslope(l-afifty)})(1+e^{-dslope(l-dfifty)})}$$

where the parameters *aslope* and *dslope* affects the ascending and descending steepness of the curve and the parameter *afifty* and *dfifty* is the age at which selectivity equals 0.5. In Model 2, the double logistic curve is also used but a penalty that is related to the differences in selectivity between ages is added to the log likelihood. This is accomplished by taking the second difference of the log selectivity

$$sel\_penalty = \lambda_5 \sum_{a=5}^{a=25} (\{\ln(sel_a) - \ln(sel_{a-1})\} - \{\ln(sel_{a-1}) - \ln(sel_{a-2})\})^2$$

where the penalty weighting factor λ_5 was set to 40. In Model 3, the asymptotic logistic curve was used for selectivity.

The likelihood components for the three models are shown in Table 9, and the estimated fishery and survey selectivities are shown in Figure 3. The double logistic curve produces the lowest negative log-likelihood, but is marked by a sharply declining curve at older ages. For example, 23 year old POP show twice the selectivity of those 24 years old (0.50 to 0.24). Adding the selectivity penalty smoothes the curve, but reduces the number of ages for which POP would be fully selected and increases the age at 50% selectivity on the ascending limb from 7.20 to 8.08. With an asymptotic curve, the age at 50% selectivity is lowered to 6.63. The asymptotic curve produces a higher negative log likelihood than either of the other two curves, with differences occurring primarily in the recruitment, unbiased fishery age composition, and survey age composition components. However, the fit to the fishery length composition is improved. Much of the higher negative log likelihood comes from older ages in the earlier fishery (1981,1982) and survey (1980-1986) age composition data, as the fits to the more recent age composition data are similar to those with the double logistic curve because the population primarily consists of fish less than 25 years. Although the asymptotic logistic curve does not produce the lowest negative log-likelihood, it does produce: 1) an overall reasonable fit to the data (particularly recent age compositions); 2) an easily interpretable fishery selectivity pattern; and 3) more conservative estimates of total biomass. For these reasons the logistic curve (Model 3) is used to produce the results below, although evaluation of alternative fishery selectivity curves should proceed in the future.

Biomass Trends

The estimated survey biomass index begins with 773,620 t in 1960, declines to 113,758 t in 1978, and increases to 501,568 t in 1995 and remains at approximately that level, with a 2002 estimate of 500,933 t (Figure 4). The survey point estimates are used in a relative sense rather than in an absolute sense, with a survey catchability (q) estimated at 1.47 rather than fixed at 1.0. Because the Aleutian Islands survey biomass estimates are taken as an index for the entire BSAI area, it is reasonable to expect that the q would be below 1.0 to the extent that the total BSAI biomass is higher than the Aleutian Islands biomass. One factor that may cause an increase in survey catchability is the expansion of survey trawl estimates to untrawlable areas (Kreiger and Sigler 1996). The fit to the CPUE index is shown in Figure 5.

The total biomass showed a similar trend as the survey biomass, with the 2002 total biomass estimated as 374,809 t. The estimated time series of total biomass, spawning biomass, and recruitment are given in Table 10. The estimated numbers at age are shown in Table 11.

Age/size compositions

The fishery age compositions, biased and unbiased, are shown in Figures 6 and 7 respectively. As noted above, the observed proportion in the binned age 25+ group for years 1981 and 1982 is higher than the estimated proportion, although the fits improve in recent years (Figure 7). The fishery length compositions are shown in Figure 8; some of the lack of fit in the mid- to late-1980s is attributable to the low sample size of lengths observed from a reduced fishery. The survey age compositions (Figure 9) show a similar pattern as the unbiased fishery age compositions in that the age 25+ group is fit better in recent years (1994-2000) than earlier years (1980-1986). The fit to the 2002 survey length composition data appears reasonable (Figure 10).

Fishing Mortality

The estimates of instantaneous fishing mortality for POP range from highs during the 1970’s to low levels in the 1980’s (Fig. 11). Relative to the estimated $F_{35\%}$ level, the stocks in both the eastern Bering Sea and Aleutian Islands were overfished during considerable portions of this period (Figure 11). Fishing mortality rates since the early 1980's, however, have moderated considerably due to the phase out of the foreign fleets and quota limitations imposed by the North Pacific Fishery Management Council. The average fishing mortality from 1965 to 1980 was 0.25, whereas the average from 1981 to 2001 was 0.03.

Recruitment

For both the eastern Bering Sea and Aleutian Islands, year class strength varies widely (Figure 12; Table 10). The relationship between spawning stock and recruitment also displays a high degree of variability (Figure 13). The 1962 year class is particularly large, more than twice any other estimated recruitment. Recruitment appears to be lower in early 1990s than in the mid-1980s, but the recent observations are based upon cohorts that have not been extensively observed in the available data.

Projections and Harvest Alternatives

The reference fishing mortality rate for Pacific ocean perch is determined by the amount of reliable population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Estimates of $F_{0.40}$, $F_{0.35}$, and $SPR_{0.40}$ were obtained from a spawner-per-recruit analysis. Assuming that the average recruitment from the 1977-1999 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{0.40}$ is calculated as the product of $SPR_{0.40}$ * equilibrium recruits, and this quantity is 137,390 t. The year 2003 spawning stock biomass is estimated as 135,000 t. Since reliable estimates of the 2003 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B<B_{0.40}$ (135,000 t < 137,390, t), POP reference fishing mortality is defined in tier 3b. For this tier, F_{ABC} is constrained to be $\leq F_{0.40}$, and F_{OFL} is constrained to be $\leq F_{0.35}$; the values of $F_{0.40}$ and $F_{0.35}$ are 0.0480 and 0.057, respectively. Under the guidelines of tier 3b of Amendment 56, we calculate the F_{ABC} as $\{F_{0.40}$ x $(SPB_{2002}/SPB_{0.40}$ - 0.05)/(1-0.05)$\}$. This procedure produces an F_{ABC} of 0.047 and an ABC estimate for the Aleutian Islands region of approximately 15,071 t. This ABC is approximately 305 t higher than last year's recommendation of 14,766 t. The estimated catch level for year 2003 associated with the overfishing level of F = 0.056 is 17,856 t. A summary of these values is below.

2003 SSB estimate (B)	=	135,000 t
$B_{0.40}$	=	137,390 t
$F_{0.40}$	=	0.048
F_{ABC}	=	0.047
$F_{0.35}$	=	0.057
F_{OFL}	=	0.056

Harvest rates producing maximum sustainable yield for many stocks of rockfish off the west coast of the continental U.S. may be lower than the commonly used $F_{0.40}$ values, based upon a Baysian meta-analysis of stock-recruitment relationships (Dorn 2002). For example, the MSY rate for the west coast stock of POP was $F_{0.70}$. However, Dorn's analysis also indicates that eastern Bering Sea and Aleutian Islands POP were the most resilient stocks in his analysis, and produced MSY harvest rates of less that $F_{0.30}$. Thus, the $F_{0.40}$ harvest rates used in this assessment appear to be appropriate, although examination of the spawner-recruit relationships should be re-evaluated as more data is collected.

Projections and Harvest Alternatives

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2002 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2003 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2002. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2003, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2003 recommended in the assessment to the *max* F_{ABC} for 2003. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)
>
> *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
>
> *Scenario 4*: In all future years, F is set equal to the 1997-2001 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

The recommended F_{ABC} and the maximum F_{ABC} are equivalent in this assessment, and five-year projections of the mean spawning stock biomass, fishing mortality rate, and harvest for the remaining four scenarios are shown in Table 12.

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether the Pacific ocean perch stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2003, then the stock is not overfished.)
>
> *Scenario 7*: In 2003 and 2004, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2005 under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that the BSAI Pacific ocean perch stock is neither overfished or approaching an overfished condition. With regard to assessing the current stock level, the expected stock size in the year 2003 of scenario 6 is 1.12 times its $B_{35\%}$ value of 120,216 t. With regard to whether Pacific ocean perch is likely to be overfished in the future, the expected stock size in 2005 of scenario 7 is 1.09 times the $B_{35\%}$ value.

OTHER CONSIDERATIONS

This combination of the eastern Bering Sea and Aleutian Islands management areas motivates consideration of the criteria to be used to divide the ABC among the areas. Because the AI trawl survey spans the two management areas, one option is to use the proportional survey biomass from the two areas to partition the ABCs. The average biomass from 1991-2002 in the AI management area is 454,656 t, whereas the average from the southern Bering Sea is 13,399 t; thus 97% of the estimated Aleutians Islands survey biomass occurs in the Aleutian Islands management area. Because the Aleutian Islands survey does not cover the EBS slope, it may be useful to consider the 2002 EBS slope survey biomass of 72,685 t. The combined biomass in the EBS management area (13,399 t +72,685 t=86,084 t) is 16% of the combined BSAI biomass from both surveys of 540,740 t. Thus, it is recommended that 16% of the ABC, or 2,411 t, be allocated to the EBS region and 84%, or 12,660 t, be allocated to the AI region.

As in previous years, it is recommended that the Aleutians Islands portion of the ABC be partitioned among management subareas in proportion to the estimated biomass. The five most recent trawl surveys (1991, 1994, 1997, 2000, and 2002; Table 13), indicate that the average POP biomass was distributed in the Aleutian Islands region as follows:

	Biomass (%)
Eastern subarea (541):	27.6%
Central subarea (542):	26.3%
Western subarea (543):	46.1%
Total	100%

Under these proportions, the recommended ABCs are 3,494 t for area 541, 3,330 t for area 542, and 5,836 t for area 543.

FUTURE RESEARCH OBJECTIVES

In future assessments, further evaluation of fishery and survey selectivity curves may prove worthwhile, including alternatives to the logistic and double logistic curves.

SUMMARY

The management parameters for Pacific ocean perch as presented in this assessment are summarized as follows:

M	0.05
$F_{35\%}$	0.057
$F_{40\%}$	0.048
Equil. spawner biomass ($F_{40\%}$)	137,390 t
2003 spawner biomass	135,000 t
$F_{abc\ (adjusted)}$	0.047
ABC (adjusted $F_{40\%}$)	15,071 t
$F_{overfishing}$ (adjusted $F_{35\%}$)	0.056
Overfishing Level	17,856 t

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Table 1. Estimated removals of Pacific ocean perch (*S. alutus*, t) since implementation of the Magnuson Fishery Conservation and Management Act of 1976.

	Eastern Bering Sea			Aleutian Islands			BSAI
Year	Foreign	JVP	DAP	Foreign	JVP	DAP	Total catch
1977	2,654	--	--	8,080	--	--	10,734
1978	2,221	--	--	5,286	--	--	7,507
1979	1,723	--	--	5,487	--	--	7,210
1980	1,050	47	--	4,700	Tr	--	5,797
1981	1,221	1	--	3,618	4	--	4,844
1982	212	3	8	1,012	2	--	1,237
1983	116	97	7	272	8	--	500
1984	156	134	1,122	356	273	2	2,043
1985	35	32	629	Tr	215	72	983
1986	16	117	375	Tr	160	98	766
1987	5	50	768	0	500	391	1,714
1988	0	51	874	0	1,513	362	2,800
1989	0	31	2,570	0	Tr	2,101	4,702
1990	0	0	6,344	0	0	11,838	18,182
1991	0	0	5,339	0	0	2,831	8,170
1992	0	0	3,309	0	0	10,278	13,587
1993	0	0	3,746	0	0	13,330	17,076
1994	0	0	1,687	0	0	10,865	12,552
1995	0	0	1,207	0	0	10,303	11,510
1996	0	0	2,855	0	0	12,827	15,682
1997	0	0	817	0	0	12,648	13,465
1998	0	0	1,017	0	0	9,051	10,068
1999	0	0	381	0	0	11,880	12,261
2000	0	0	451	0	0	8,577	9,028
2001	0	0	888	0	0	7,924	8,812
2002*	0	0	544	0	0	9228	9,772

Tr = trace, JVP = Joint Venture Processing, DAP = Domestic Annual Processing.
Source: PacFIN, NMFS Observer Program, and NMFS Alaska Regional Office.
*Estimated removals through September 7, 2002.

Table 2. Estimated retained and discarded catch (t), and percent discarded, of Pacific ocean perch from the eastern Bering Sea (EBS) and Aleutian Islands (AI) regions.

	EBS			AI			BSAI		
Year	Retained	Discarded	Percent Discarded	Retained	Discarded	Percent Discarded	Retained	Discard	Percent Discarded
1990	5,069	1,275	20.10	10,288	1,551	13.10	15,357	2,826	15.54
1991	4,112	1,227	22.98	1,851	980	34.62	5,963	2,207	27.01
1992	2,784	525	15.87	8,686	1,592	15.49	11,470	2,117	15.58
1993	2,602	1,144	30.54	11,438	1,892	14.19	14,040	3,036	17.78
1994	1,281	406	24.07	9,491	1,374	12.65	10,772	1,780	14.18
1995	839	368	30.49	8,603	1,700	16.50	9,442	2,068	17.97
1996	2,522	333	11.66	9,832	2,995	23.35	12,354	3,328	21.22
1997	539	278	34.03	10,855	1,793	14.18	11,394	2,071	15.38
1998	821	201	19.67	8,030	940	10.48	8,851	1,141	11.42
1999	247	134	35.17	10,406	1,473	12.40	10,653	1,607	13.11
2000	229	221	49.11	7,844	734	8.56	8,073	955	10.58
2000	229	221	49.11	7,844	734	8.56	8,073	955	10.58
2001	396	492	55.41	6,586	1,338	16.89	6,982	1,830	20.77
2002*	203	341	62.68	8673	555	6.01	8,876	896	9.17

*Estimated removals through September 7, 2002.
Source: NMFS Alaska Regional Office

Table 3. Estimated catch (t) of Pacific ocean perch in Aleutian Islands and eastern Bering Sea trawl surveys, and the eastern Bering Sea hydroacoustic survey.

		Area	
Year	AI	BS	BS-Hydroacoustic
1977		0.01	
1978		0.13	0.01
1979		3.08	
1980	71.47	0.00	
1981		13.98	
1982	0.24	12.09	
1983	133.30	0.16	
1984		0.00	
1985		98.57	
1986	164.54	0.00	
1987		0.01	
1988		10.43	
1989		0.00	
1990		0.02	0.01
1991	73.57	2.76	0.00
1992		0.38	0.00
1993		0.01	0.00
1994	112.79	0.00	0.02
1995		0.01	0.01
1996		1.18	0.00
1997	177.94	0.73	0.15
1998		0.01	0.00
1999		0.19	0.00
2000	140.82	22.90	0.45
2001		0.11	
2002		13.18	0.31

Table 4. Proportional catch (by weight) of Aleutians Islands POP in the foreign/joint venture fisheries and the domestic fishery by depth.

Depth	Foreign and JV (1977-1988)	Domestic (1990-2001)
0-99	0.03	0.00
100-199	0.34	0.21
200-299	0.49	0.66
300-399	0.13	0.12
400-499	0.01	0.01
500-599	0.00	0.00
≥501	0.00	0.00
Observed catch	1,638	87,434
Total Catch	31,486	122,352
Sampling ratio	0.05	0.71

Table 5. Proportional catch (by weight) of Aleutians Islands POP in the foreign and joint venture fisheries and the domestic fishery by management area.

Area	Foreign and JV (1977-1988)	Domestic (1990-2001)
541	0.46	0.42
542	0.27	0.24
543	0.26	0.34
Observed catch	1,638	87434
Total Catch	31,486	122352
Sampling ratio	0.05	0.71

Table 6. Length measurements and otoliths read from the EBS and AI POP fisheries, from Chikuni (1975) and NORPAC Observer database.

	Length Measurements				Otoliths read		
Year	EBS	AI	Total		EBS	AI	Total
1964	24,150	55,599	79,749				
1965	14,935	66,120	81,055				
1966	26,458	25,502	51,960				
1967	48,027	59,576	107,603				
1968	38,370	36,734	75,104				
1969	28,774	27,206	55,980				
1970	11,299	27,508	38,807				
1971	14,045	18,926	32,971				
1972	10,996	18,926	29,922				
1973	1		1**				
1974	84		84**		84		84**
1975	1		1**		125		125**
1976	50		50**		114	19	133**
1977	1,059	2,778	3,837*		139	404	543
1978	7,926	7,283	15,209*		583	641	1,224
1979	1,045	10,921	11,966*		248	353	601
1980		3,995	3,995*			398	398
1981	1,502	7,167	8,669*		78	432	510
1982		4,902	4,902*			222	222
1983	232	441	673				
1984	1,194	1,210	2,404		72		72**
1985	300		300**		160		160**
1986		100	100**			99	99**
1987	11	384	395		11		11**
1988	306	1,366	1,672				
1989	957	91	1,048			19	19**
1990	22,228	47,198	69,426*		144	184	328
1991	8,247	8,221	16,468				
1992	13,077	24,932	38,009				
1993	8,379	26,433	34,812				
1994	2,654	11,546	14,200				
1995	272	11,452	11,724				
1996	2,967	13,146	16,113				
1997	143	10,402	10,545				
1998	989	11,106	12,095*			823	823
1999	289	3,839	4,128				
2000	284	3,382	3,666*			487	487
2001	327	2388	2,715*			258	258

*Used to create age composition.
**Not used.

Table 7. Pacific ocean perch estimated biomass (t) from the Aleutian Islands trawl surveys, by management area.

	Southern Bering Sea			Aleutian Islands			Total Aleutian Islands Survey		
Year	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
1979									
1980	6003	9966	1.66	109022	27670	0.25	115025	29410	0.26
1981									
1982									
1983	97478	89947	0.92	144080	26338	0.18	241558	93723	0.39
1984									
1985									
1986	49562	29214	0.59	220614	39909	0.18	270176	49459	0.18
1987									
1988									
1989									
1990									
1991	1501	758	0.51	349592	79318	0.23	351093	79322	0.23
1992									
1993									
1994	18217	11685	0.64	365401	87600	0.24	383618	88376	0.23
1995									
1996									
1997	12099	7008	0.58	613174	96405	0.16	625272	96659	0.15
1998									
1999									
2000	18870	10150	0.54	492836	89535	0.18	511706	90109	0.18
2001									
2002	16311	6637	0.41	452277	76693	0.17	468588	76979	0.16

Table 8. Length measurements and otoliths read from the Aleutian Islands surveys.

Year	Length measurements	Otoliths read
1980	20796	872
1983	22873	2299
1986	14804	1860
1991	14262	807
1994	18922	788
1997	22823	1172
2000	21972	1219
2002	20285	NA

Table 9. Negative log likelihood fits of various model components for BSAI POP models with a double logistic fishery selectivity curve (Model 1), a double logistic fishery selectivity curve that penalize non-smoothness (Model 2), and a asymptotic fishery selectivity curve (Model 3).

Likelihood component	**Model 1**	**Model 2**	**Model 3**
Recruitment	-0.800	-7.882	16.946
AI survey biomass	3.045	2.853	2.753
CPUE	10.959	11.853	12.010
Catch	0.012	0.023	0.007
Fishing mortality penalty	8.484	9.024	6.885
fishery biased age comps	2.845	3.583	3.905
fishery unbiased age comps	24.712	20.724	33.364
fishery length comps	186.340	200.600	176.083
AI survey age comps	32.140	32.581	49.266
AI survey length comps	6.878	6.949	7.106
selectivity penalty	0.000	10.293	0.000
parameters	113	113	111
- ln likelihood	274.614	290.600	308.325

Table 10. Estimated time series of POP total biomass (t), spawner biomass (t), and recruitment (thousands) for each region.

	Total Biomass (ages 3+)		Spawner Biomass (ages 3+)		Recruitment (age 3)	
	Assessment Year		Assessment Year		Assessment Year	
Year	2002	2001	2002	2001	2002	2001
1960	561,921	561,144	114,107	114,177	25,197	25,606
1961	609,986	609,147	138,315	138,303	204,876	205,462
1962	602,248	601,283	155,775	155,647	47,598	46,643
1963	613,595	612,558	182,527	182,277	28,006	27,952
1964	602,833	602,030	195,988	195,628	153,113	156,690
1965	543,354	542,277	173,087	172,645	461,176	455,961
1966	454,386	453,248	137,215	136,712	25,272	25,505
1967	383,588	382,434	102,467	101,957	37,492	38,268
1968	345,892	344,614	78,942	78,492	102,591	101,485
1969	299,344	297,994	63,683	63,212	25,162	25,246
1970	270,143	268,735	58,465	57,982	25,077	25,060
1971	210,203	208,724	46,450	45,988	25,712	25,510
1972	193,455	191,893	46,873	46,375	25,289	24,948
1973	166,274	164,602	43,728	43,186	28,272	27,590
1974	161,484	159,688	46,253	45,659	23,767	23,178
1975	133,858	131,885	39,683	39,054	27,824	26,811
1976	116,422	114,257	35,180	34,508	21,390	20,615
1977	94,731	92,354	27,880	27,159	21,942	21,286
1978	92,574	89,991	26,530	25,760	39,715	39,144
1979	97,375	94,512	26,377	25,543	75,567	74,110
1980	104,387	101,320	26,307	25,399	68,583	68,579
1981	117,772	114,282	26,749	25,762	102,460	99,329
1982	130,402	126,675	28,015	26,935	34,954	35,570
1983	147,964	144,154	31,544	30,353	46,358	48,145
1984	175,759	171,521	36,207	34,914	160,916	156,756
1985	197,876	193,448	42,080	40,641	42,298	42,992
1986	222,267	217,675	49,003	47,443	60,277	60,440
1987	253,396	247,986	57,364	55,701	139,545	131,036
1988	279,932	274,097	67,865	66,051	56,418	57,101
1989	308,405	301,966	78,082	76,160	104,434	102,071

Table 10, continued.

	Total Biomass (ages 3+)		Spawner Biomass (ages 3+)		Recruitment (age 3)	
	Assessment Year		Assessment Year		Assessment Year	
Year	2002	2001	2002	2001	2002	2001
1990	332,277	325,377	88,212	86,196	56,301	56,501
1991	342,181	334,410	94,520	92,313	77,332	71,489
1992	358,208	349,786	103,904	101,520	34,892	34,115
1993	365,232	356,264	111,747	109,123	24,810	24,905
1994	364,851	355,332	117,449	114,587	19,361	18,090
1995	365,758	359,016	124,799	121,585	19,099	
1996	367,803	362,706	131,368	127,824		
1997	364,671	361,420	134,769	130,930		
1998	363,620	362,244	137,594	133,460		
1999	365,625	366,081	139,833	136,101		
2000	366,021	368,123	139,935	136,691		
2001	370,265	373,807	140,676	138,172		
2002	374,809		140,832			

Table 11. Estimated numbers (millions) of Pacific ocean perch in the BSAI region

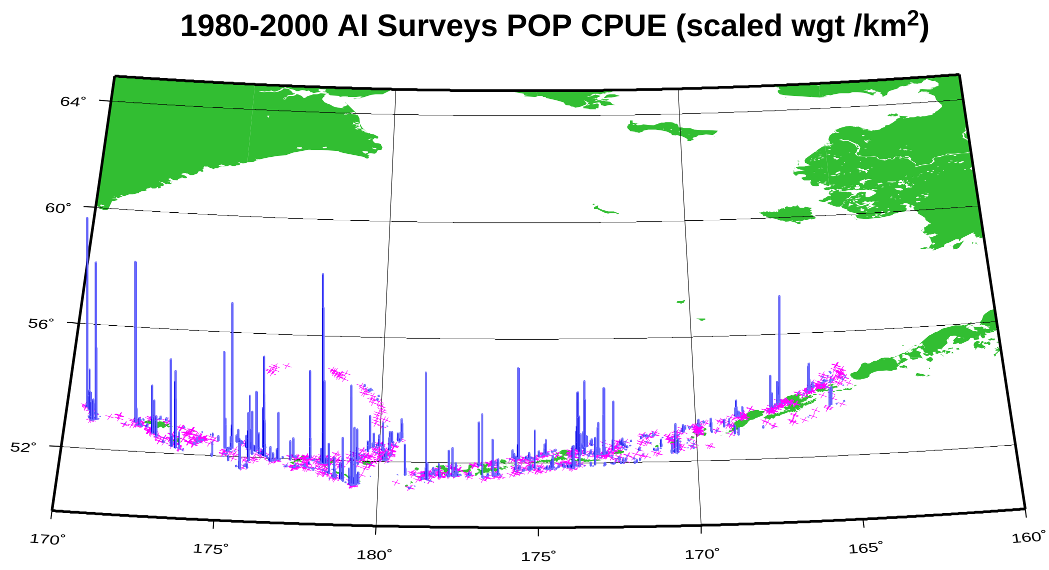
	Age																					
Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+
1960	25.2	18.2	21.0	22.9	23.4	931.8	21.2	19.2	17.4	15.8	14.5	13.5	12.5	11.7	11.0	10.4	9.9	9.2	8.7	8.4	8.0	7.7	51.2
1961	204.9	24.0	17.3	20.0	21.8	22.1	876.3	19.9	18.0	16.4	14.9	13.7	12.7	11.8	11.0	10.3	9.7	9.3	8.6	8.2	7.9	7.5	55.3
1962	47.6	194.9	22.8	16.4	18.7	19.4	19.3	764.4	17.4	15.7	14.3	13.0	11.9	11.0	10.3	9.6	9.0	8.5	8.1	7.5	7.1	6.9	54.8
1963	28.0	45.3	185.4	21.7	15.5	17.3	17.8	17.7	700.5	15.9	14.4	13.1	11.9	10.9	10.1	9.4	8.8	8.3	7.8	7.4	6.9	6.5	56.5
1964	153.1	26.6	43.1	176.1	20.3	13.9	15.2	15.6	15.4	611.5	13.9	12.6	11.4	10.4	9.5	8.8	8.2	7.7	7.2	6.8	6.5	6.0	55.1
1965	461.2	145.6	25.3	40.8	160.8	16.1	10.3	11.3	11.5	11.4	453.3	10.3	9.3	8.5	7.7	7.1	6.5	6.1	5.7	5.3	5.0	4.8	45.3
1966	25.3	438.7	138.5	24.0	36.8	120.6	11.2	7.1	7.7	7.9	7.8	310.6	7.1	6.4	5.8	5.3	4.8	4.5	4.2	3.9	3.7	3.5	34.3
1967	37.5	24.0	417.1	131.1	21.5	26.9	80.8	7.4	4.7	5.1	5.2	5.2	205.9	4.7	4.2	3.8	3.5	3.2	3.0	2.8	2.6	2.4	25.0
1968	102.6	35.7	22.9	394.8	117.9	16.0	18.4	54.7	5.0	3.2	3.5	3.5	3.5	139.4	3.2	2.9	2.6	2.4	2.2	2.0	1.9	1.7	18.6
1969	25.2	97.6	33.9	21.6	351.7	83.9	10.3	11.7	34.8	3.2	2.0	2.2	2.3	2.2	88.7	2.0	1.8	1.7	1.5	1.4	1.3	1.2	12.9
1970	25.1	23.9	92.8	32.1	19.7	278.4	62.3	7.6	8.7	25.7	2.4	1.5	1.6	1.7	1.7	65.5	1.5	1.3	1.2	1.1	1.0	0.9	10.4
1971	25.7	23.9	22.8	87.8	28.6	14.0	178.6	39.6	4.8	5.5	16.3	1.5	0.9	1.0	1.1	1.0	41.6	0.9	0.9	0.8	0.7	0.6	7.2
1972	25.3	24.5	22.7	21.6	80.8	23.6	11.0	139.2	30.8	3.8	4.3	12.7	1.2	0.7	0.8	0.8	0.8	32.4	0.7	0.7	0.6	0.6	6.1
1973	28.3	24.1	23.3	21.5	19.7	63.5	17.3	8.0	101.8	22.6	2.7	3.1	9.3	0.9	0.5	0.6	0.6	0.6	23.7	0.5	0.5	0.4	4.9
1974	23.8	26.9	22.9	22.1	20.1	17.2	54.2	14.8	6.8	86.5	19.2	2.3	2.7	7.9	0.7	0.5	0.5	0.5	0.5	20.1	0.5	0.4	4.5
1975	27.8	22.6	25.6	21.7	20.0	15.4	12.3	38.3	10.4	4.8	61.2	13.6	1.7	1.9	5.6	0.5	0.3	0.4	0.4	0.4	14.2	0.3	3.5
1976	21.4	26.5	21.5	24.2	19.8	15.9	11.5	9.1	28.4	7.7	3.6	45.4	10.1	1.2	1.4	4.1	0.4	0.2	0.3	0.3	0.3	10.6	2.8
1977	21.9	20.3	25.2	20.3	21.8	14.6	10.8	7.7	6.1	19.1	5.2	2.4	30.4	6.7	0.8	0.9	2.8	0.3	0.2	0.2	0.2	0.2	9.0
1978	39.7	20.9	19.4	23.9	18.9	18.6	12.0	8.8	6.3	5.0	15.6	4.2	2.0	24.9	5.5	0.7	0.8	2.3	0.2	0.1	0.1	0.1	7.5
1979	75.6	37.8	19.9	18.4	22.3	16.6	15.9	10.3	7.5	5.4	4.3	13.4	3.6	1.7	21.3	4.7	0.6	0.7	1.9	0.2	0.1	0.1	6.5
1980	68.6	71.9	35.9	18.9	17.2	19.7	14.3	13.7	8.8	6.5	4.6	3.7	11.5	3.1	1.4	18.3	4.1	0.5	0.6	1.7	0.2	0.1	5.7
1981	102.5	65.2	68.4	34.1	17.7	15.4	17.4	12.6	12.0	7.7	5.7	4.1	3.2	10.1	2.7	1.3	16.1	3.6	0.4	0.5	1.5	0.1	5.1
1982	35.0	97.5	62.1	65.0	32.1	16.1	13.8	15.5	11.2	10.7	6.9	5.1	3.6	2.9	9.0	2.4	1.1	14.3	3.2	0.4	0.4	1.3	4.7
1983	46.4	33.2	92.7	59.0	61.7	30.2	15.1	12.9	14.5	10.5	10.0	6.5	4.7	3.4	2.7	8.4	2.3	1.1	13.4	3.0	0.4	0.4	5.6
1984	160.9	44.1	31.6	88.2	56.1	58.4	28.6	14.3	12.2	13.7	9.9	9.5	6.1	4.5	3.2	2.6	8.0	2.2	1.0	12.7	2.8	0.3	5.7
1985	42.3	153.1	41.9	30.1	83.6	52.7	54.7	26.8	13.3	11.4	12.8	9.3	8.9	5.7	4.2	3.0	2.4	7.4	2.0	0.9	11.9	2.6	5.6
1986	60.3	40.2	145.6	39.9	28.6	79.2	49.8	51.7	25.3	12.6	10.8	12.1	8.8	8.4	5.4	4.0	2.8	2.3	7.0	1.9	0.9	11.2	7.8
1987	139.5	57.3	38.3	138.5	37.9	27.1	75.0	47.2	48.9	24.0	11.9	10.2	11.5	8.3	8.0	5.1	3.8	2.7	2.1	6.7	1.8	0.8	18.0
1988	56.4	132.7	54.5	36.4	131.5	35.8	25.5	70.7	44.5	46.1	22.6	11.2	9.6	10.8	7.8	7.5	4.8	3.5	2.5	2.0	6.3	1.7	17.8
1989	104.4	53.7	126.3	51.9	34.6	124.0	33.7	24.0	66.4	41.8	43.3	21.2	10.6	9.1	10.2	7.4	7.0	4.5	3.3	2.4	1.9	5.9	18.3
1990	56.3	99.3	51.0	120.1	49.2	32.4	115.7	31.4	22.4	61.9	39.0	40.4	19.8	9.9	8.4	9.5	6.9	6.6	4.2	3.1	2.2	1.8	22.6
1991	77.3	53.6	94.5	48.5	112.9	44.5	28.8	102.6	27.9	19.8	54.9	34.5	35.8	17.5	8.7	7.5	8.4	6.1	5.8	3.8	2.8	2.0	21.6
1992	34.9	73.6	50.9	89.8	45.9	105.1	41.1	26.6	94.8	25.7	18.3	50.7	31.9	33.1	16.2	8.1	6.9	7.8	5.6	5.4	3.5	2.5	21.8
1993	24.8	33.2	70.0	48.4	84.8	42.3	95.7	37.4	24.2	86.2	23.4	16.7	46.1	29.0	30.1	14.7	7.3	6.3	7.1	5.1	4.9	3.2	22.1
1994	19.4	23.6	31.6	66.5	45.7	77.5	38.1	86.1	33.6	21.8	77.6	21.1	15.0	41.5	26.1	27.1	13.3	6.6	5.7	6.4	4.6	4.4	22.7
1995	19.1	18.4	22.4	30.0	62.9	42.2	71.0	34.9	78.8	30.8	19.9	70.9	19.3	13.7	38.0	23.9	24.8	12.1	6.0	5.2	5.8	4.2	24.8
1996	58.2	18.2	17.5	21.3	28.4	58.3	38.8	65.2	32.0	72.4	28.3	18.3	65.2	17.7	12.6	34.9	21.9	22.8	11.1	5.5	4.8	5.3	26.7
1997	58.2	55.3	17.3	16.7	20.1	26.1	53.0	35.2	59.2	29.1	65.7	25.6	16.6	59.2	16.1	11.4	31.7	19.9	20.7	10.1	5.0	4.3	29.1
1998	58.2	55.3	52.6	16.4	15.7	18.6	23.9	48.4	32.2	54.1	26.5	60.0	23.4	15.2	54.0	14.7	10.4	28.9	18.2	18.9	9.2	4.6	30.5
1999	58.2	55.3	52.6	50.0	15.5	14.6	17.2	22.0	44.6	29.6	49.8	24.5	55.3	21.6	14.0	49.8	13.5	9.6	26.6	16.8	17.4	8.5	32.3
2000	58.2	55.3	52.6	50.0	47.3	14.4	13.4	15.7	20.1	40.8	27.1	45.6	22.4	50.6	19.7	12.8	45.5	12.4	8.8	24.4	15.3	15.9	37.4
2001	58.2	55.3	52.6	50.0	47.4	44.1	13.3	12.4	14.5	18.6	37.7	25.1	42.1	20.7	46.8	18.3	11.8	42.1	11.4	8.1	22.5	14.2	49.2
2002	58.2	55.3	52.6	50.0	47.4	44.2	40.8	12.3	11.5	13.4	17.2	34.9	23.2	39.0	19.1	43.3	16.9	10.9	39.0	10.6	7.5	20.9	58.7

Table 12. Projections of BSAI spawning biomass (t), catch (t), and fishing mortality rate for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 137,390 t and 120,216 t, respectively.

Sp. Biomass	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2002	137495	137495	137495	137495	137495	137495	137495
2003	135000	135000	135795	135458	136594	134700	135001
2004	132748	132748	136643	134969	140693	131308	132748
2005	131063	131063	137882	134900	145300	128617	130781
2006	130336	130336	139972	135698	150924	126984	129025
2007	129667	129667	142011	136467	156573	125511	127409
2008	129464	129464	144442	137637	162704	124589	126371
2009	129681	129681	147237	139182	169275	124160	125831
2010	129857	129857	149879	140620	175674	123776	125353
2011	130365	130365	152799	142357	182383	123783	125234
2012	130804	130804	155538	143968	188848	123786	125113
2013	131407	131407	158374	145706	195398	123993	125215
2014	131956	131956	161039	147331	201685	124191	125253
2015	132490	132490	163591	148888	207788	124403	125361
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2002	0.046035	0.046035	0.046034	0.046035	0.046034	0.046035	0.046034
2003	0.047045	0.047045	0.023523	0.033495	0	0.055978	0.047045
2004	0.046218	0.046218	0.023677	0.033495	0	0.054493	0.046218
2005	0.0456	0.0456	0.023901	0.033495	0	0.053315	0.054262
2006	0.045333	0.045333	0.023961	0.033495	0	0.0526	0.053493
2007	0.045087	0.045087	0.023961	0.033495	0	0.051955	0.052786
2008	0.045013	0.045013	0.023961	0.033495	0	0.051551	0.052331
2009	0.045091	0.045091	0.023961	0.033495	0	0.051363	0.052094
2010	0.045145	0.045145	0.023961	0.033495	0	0.051194	0.051877
2011	0.045293	0.045293	0.023961	0.033495	0	0.051193	0.051805
2012	0.045378	0.045378	0.023961	0.033495	0	0.051181	0.051719
2013	0.04548	0.04548	0.023961	0.033495	0	0.051242	0.051728
2014	0.045542	0.045542	0.023961	0.033495	0	0.051297	0.051707
2015	0.045596	0.045596	0.023961	0.033495	0	0.051354	0.051715
Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2002	14800.7	14800.7	14800.3	14800.4	14800.4	14800.7	14800.3
2003	15071.3	15071.3	7622.1	10801.1	0	17855.8	15071.4
2004	14742.4	14742.4	7807.86	10889.5	0	17166.1	14742.9
2005	14509.8	14509.8	8021.14	10985	0	16634.7	17202.1
2006	14438.8	14438.8	8197.14	11106.9	0	16325.3	16873.4
2007	14381.4	14381.4	8346.37	11223.8	0	16062.6	16576.3
2008	14409.9	14409.9	8504.44	11355.9	0	15923.1	16402.5
2009	14518.6	14518.6	8673.59	11505.7	0	15895.3	16339.8
2010	14605.8	14605.8	8828.12	11639.2	0	15868.1	16277.6
2011	14739.1	14739.1	8986.7	11780.8	0	15917.1	16275.6
2012	14832.9	14832.9	9129.18	11903.9	0	15948	16263.8
2013	14936.8	14936.8	9270.29	12027.9	0	16011.2	16301.9
2014	15024.3	15024.3	9404.21	12145.8	0	16072.8	16314.4
2015	15100.3	15100.3	9528.71	12253.9	0	16126.9	16344.9

Table 13. Pacific ocean perch biomass estimates (t) from the 1991, 1994, 1997, and 2000 triennial trawl surveys broken out by the three management sub-areas in the Aleutian Islands region.

	Aleutian Islands Management Sub-Areas		
Year	Western	Central	Eastern
1991	214,137	79,911	55,545
1994	184,005	80,811	100,585
1997	225,725	166,816	220,633
2000	222,584	129,740	140,512
2002	202,124	140,358	109,795
Average	209,715	119,527	125,414
Percentage	46.1%	26.3%	27.6%



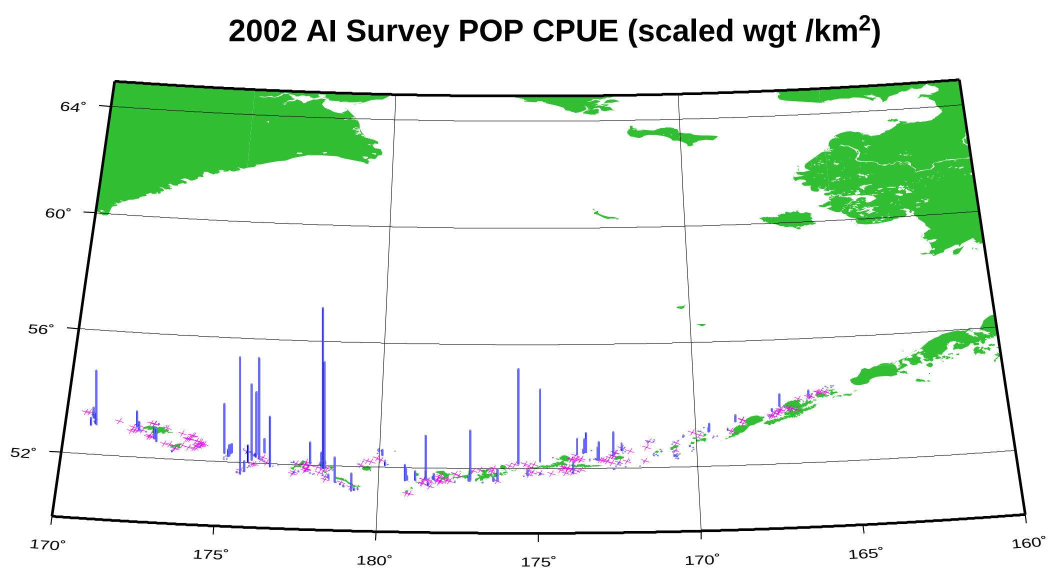


Figure 1. Scaled AI survey POP CPUE from 1980-2000 (top panel), and 2002 (bottom panel)

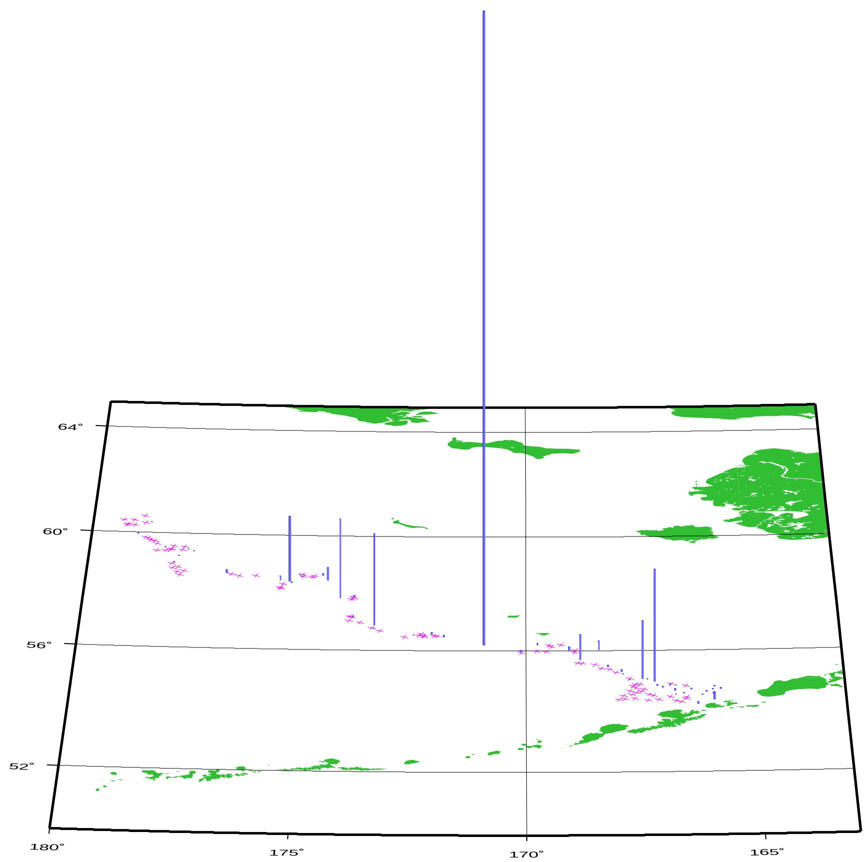


Figure 2. 2002 EBS Survey Pacific Ocean Perch CPUE (scaled wgt /ha)

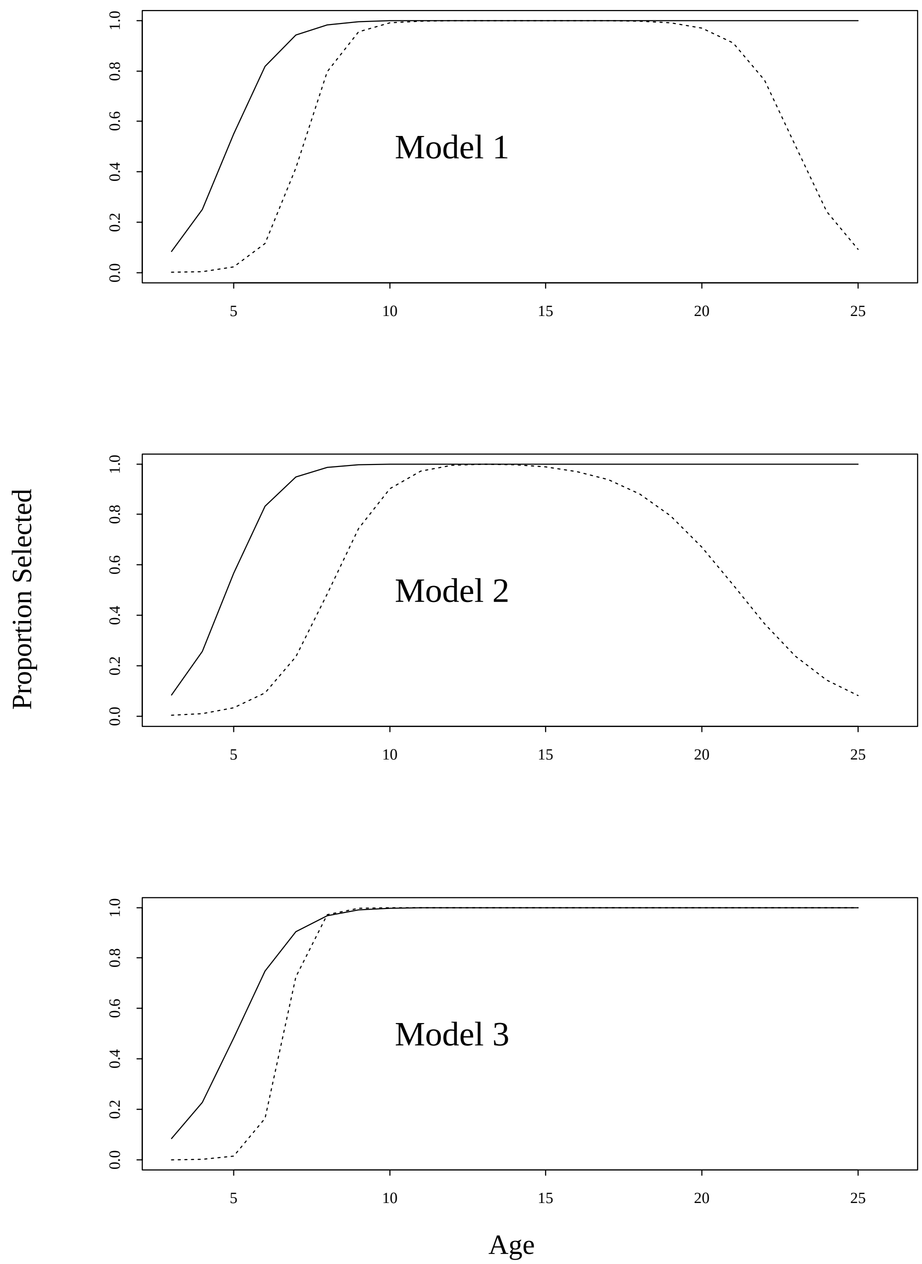


Figure 3. Estimated survey (solid line) and fishery selectivity (dashed line) for three potential models of BSAI POP.

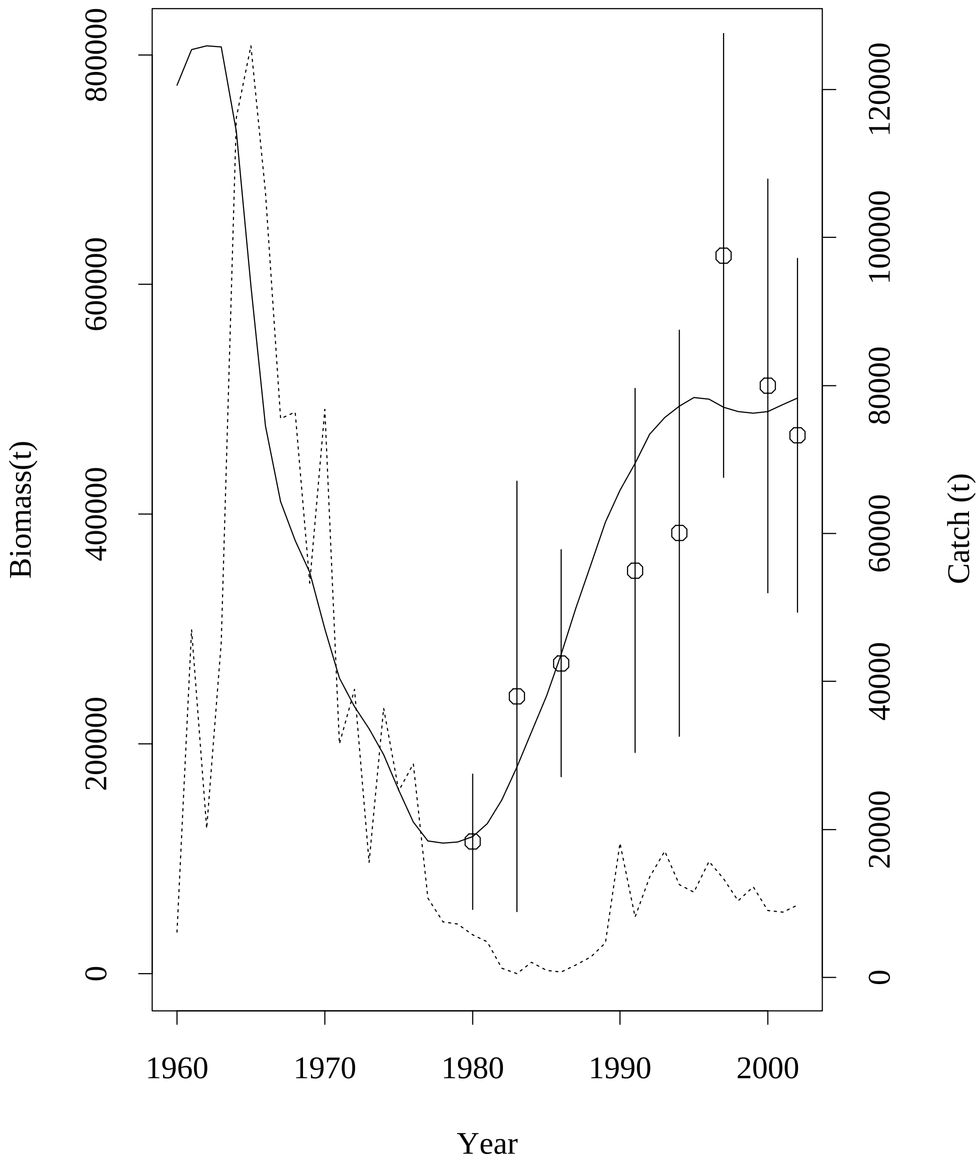


Figure 4. Observed AI survey biomass(data points, +/- 2 standard deviations), predicted survey biomass(solid line), and BSAI harvest (dashed line).

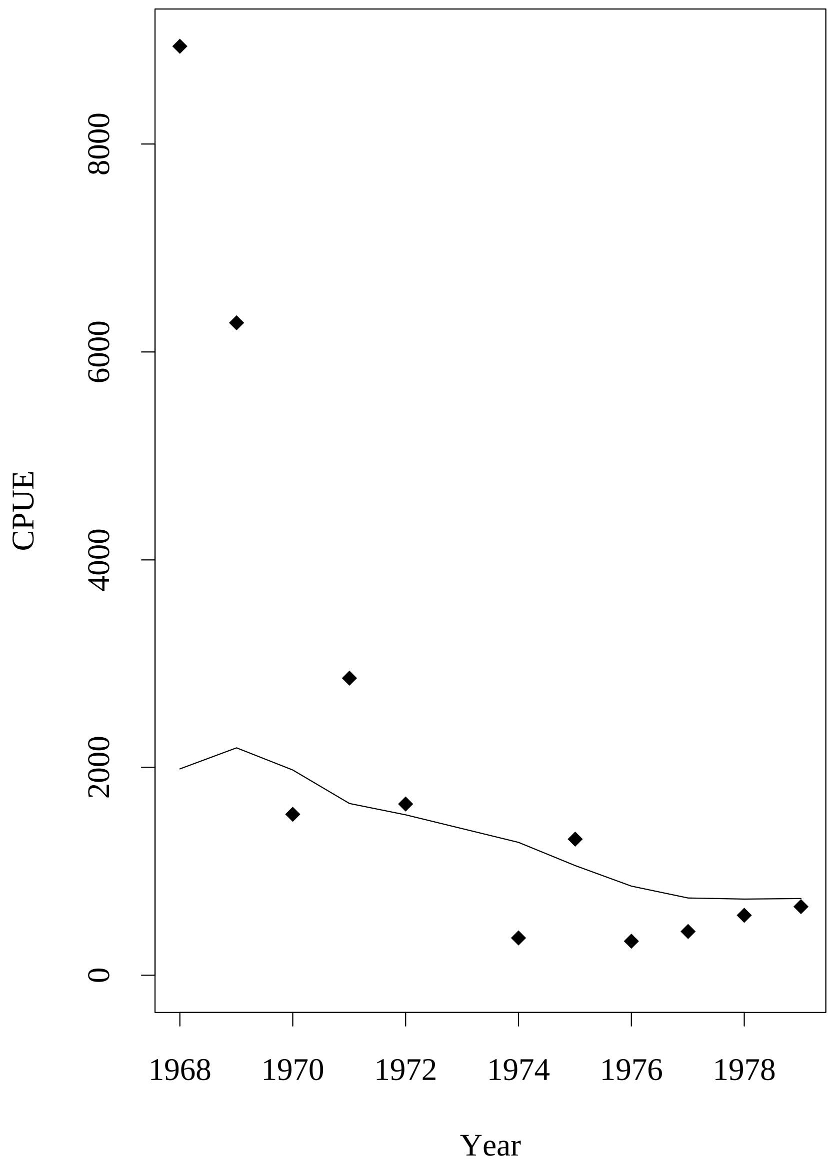


Figure 5. Observed AI CPUE (data points) and predicted CPUE (solid line) for BSAI POP.

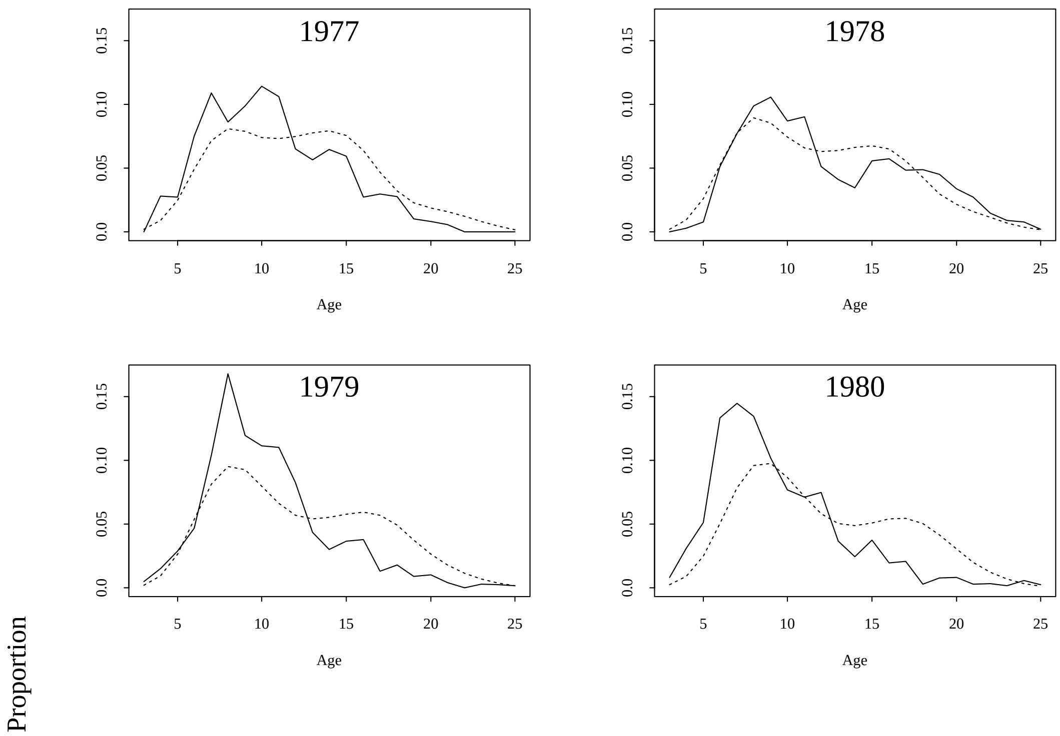


Figure 6. Fishery biased age composition by year (solid line = observed, dotted line = predicted) for BSAI POP.

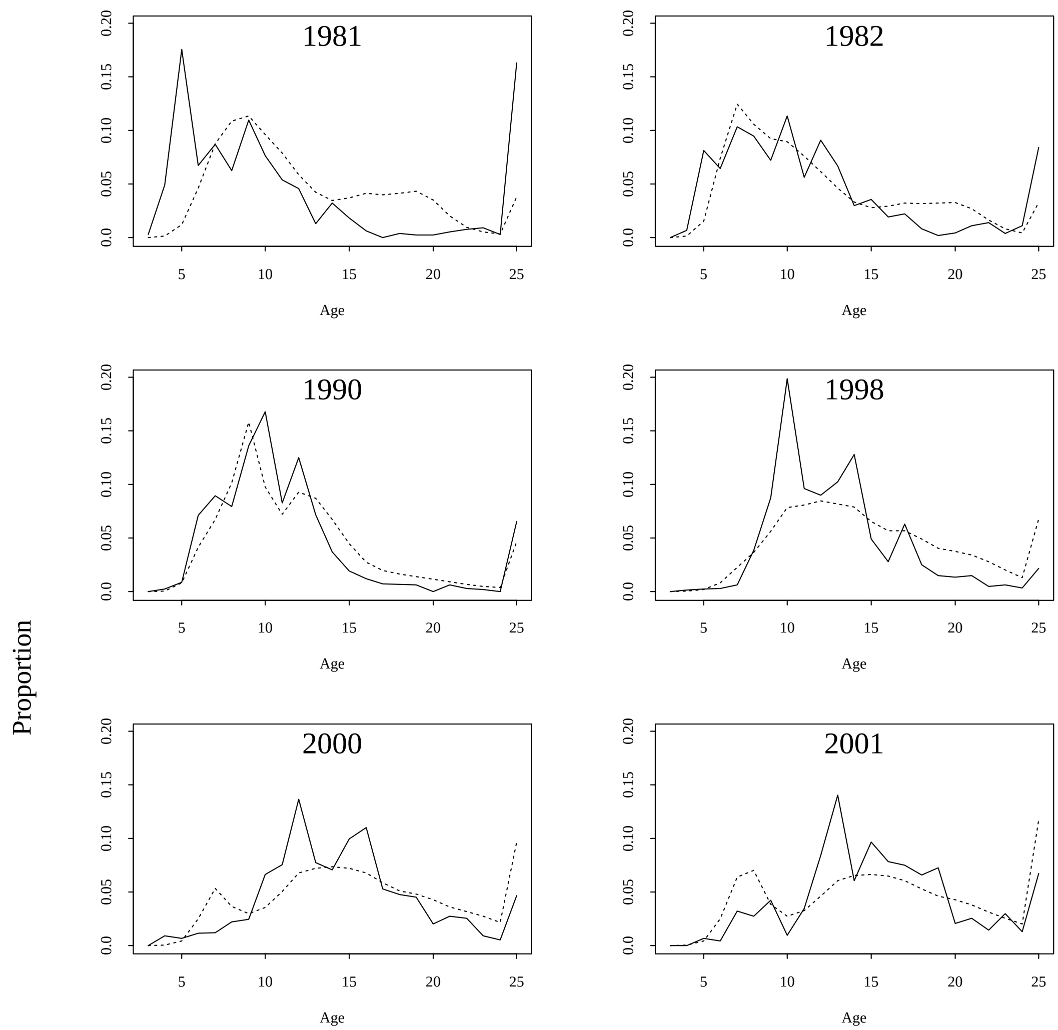


Figure 7. Fishery age composition by year (solid line = observed, dotted line = predicted) for BSAI POP.

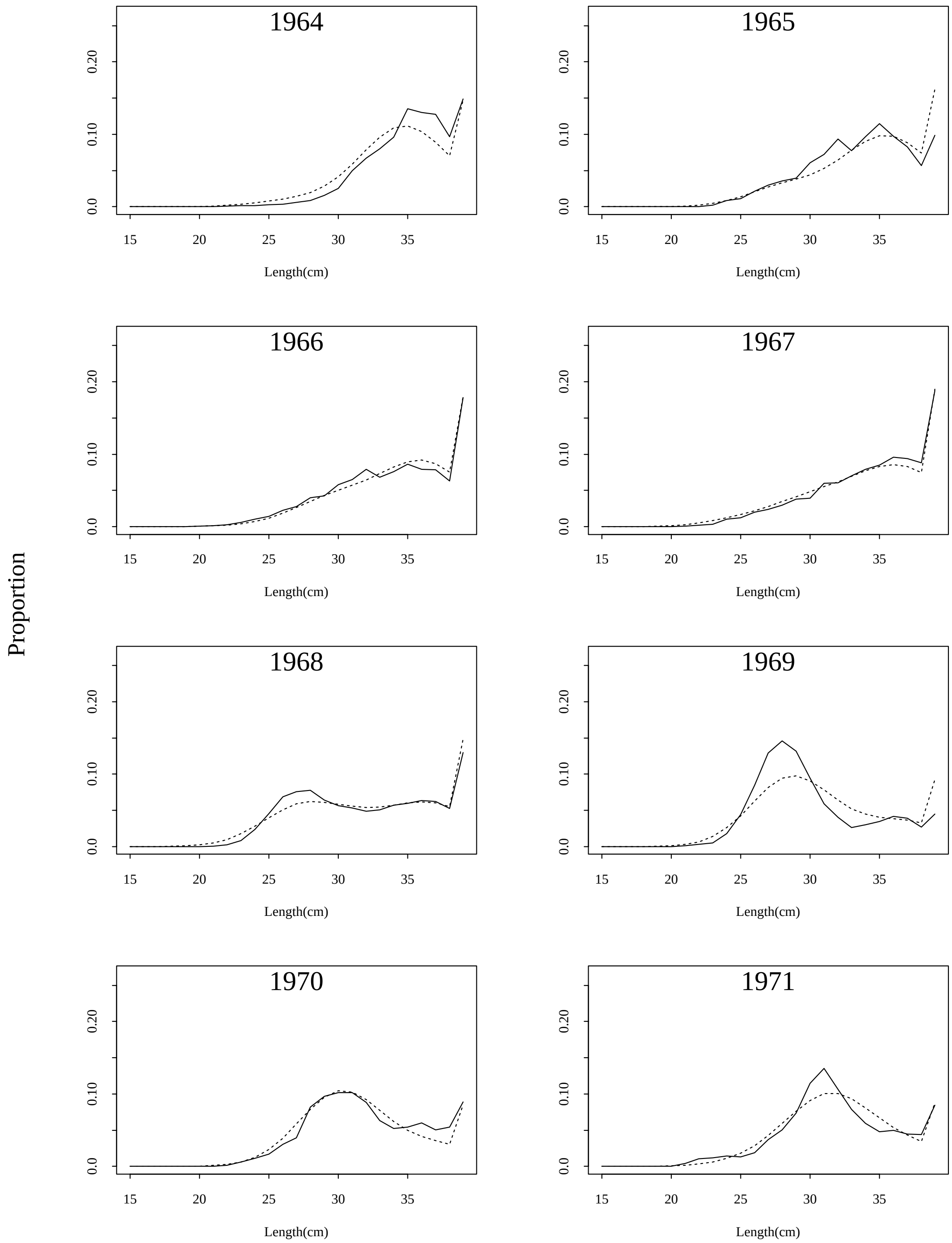


Figure 8. Fishery length composition by year (solid line = observed, dotted line = predicted) for BSAI POP.

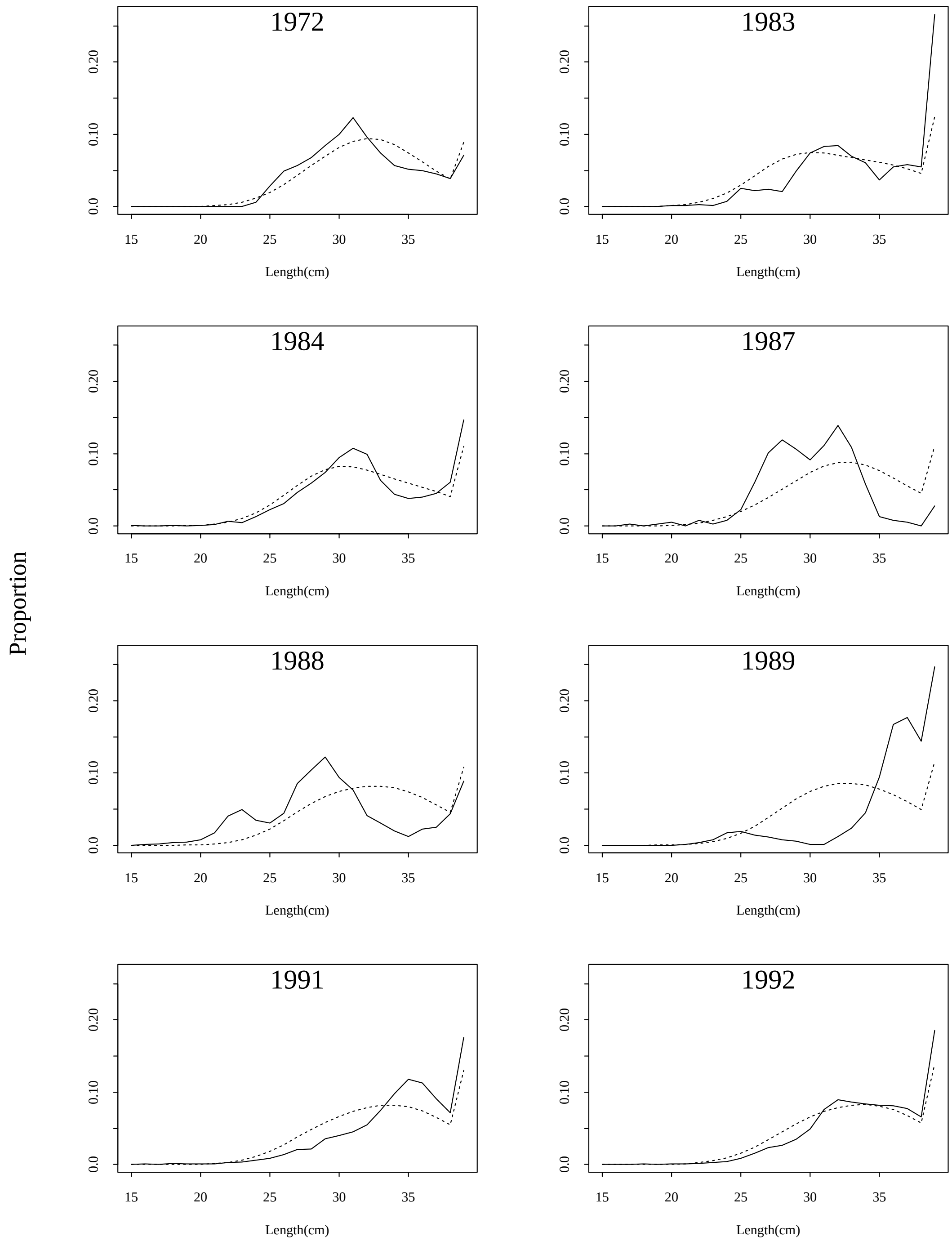


Figure 8. Fishery length composition by year (solid line = observed, dotted line = predicted) for BSAI POP.

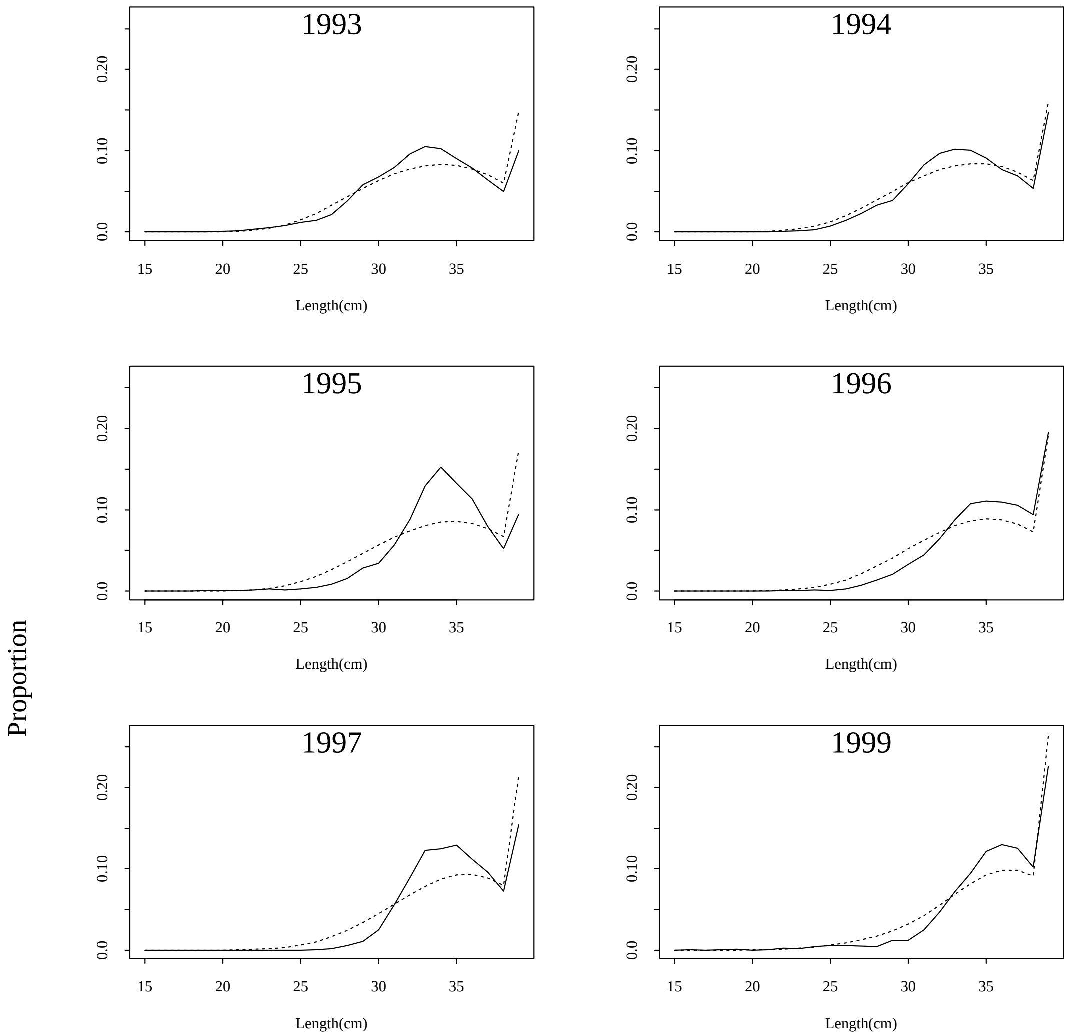


Figure 8. Fishery length composition by year (solid line = observed, dotted line = predicted) for BSAI POP.

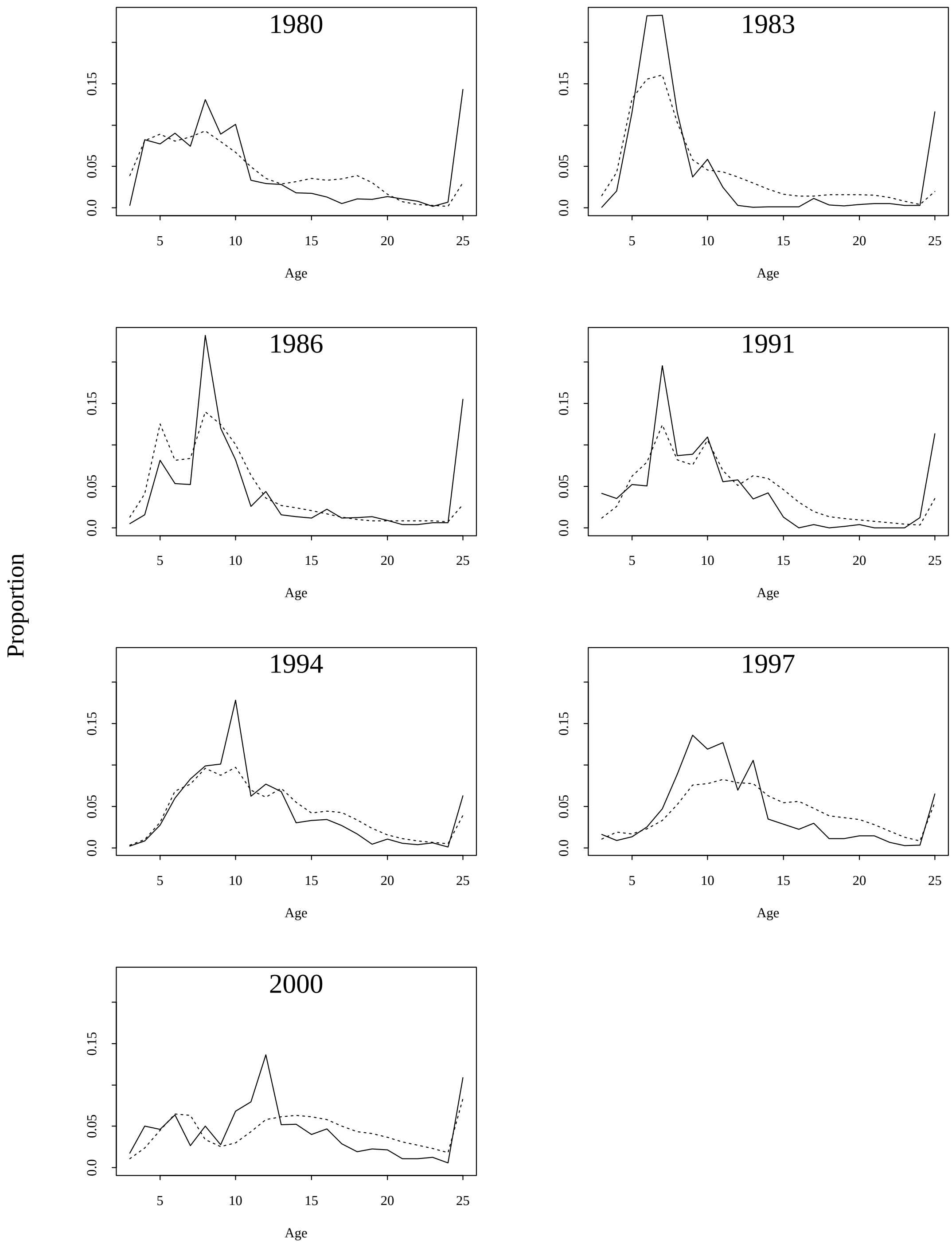
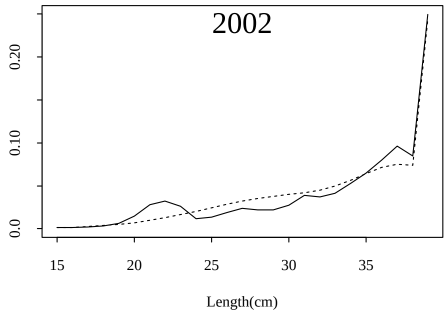


Figure 9. AI Survey age composition by year (solid line = observed, dotted line = predicted) for BSAI POP.



Proportion

Figure 10. AI Survey length composition by year (solid line = observed, dotted line = predicted) for BSAI POP.

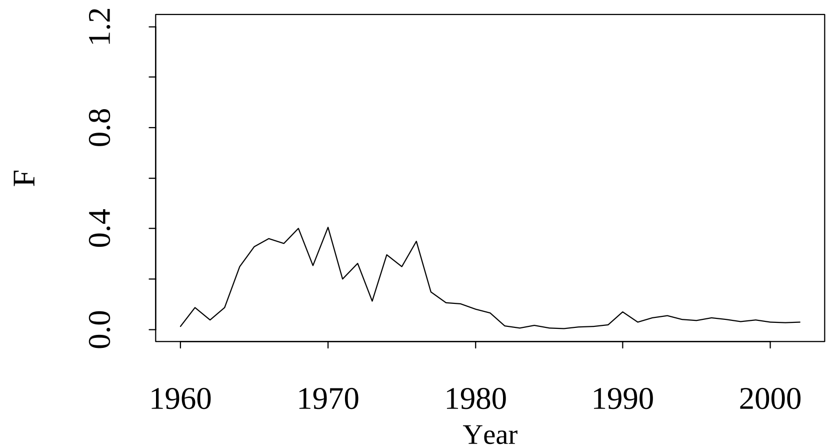


Figure 11. Estimated fully selected fishing mortality for BSAI POP.

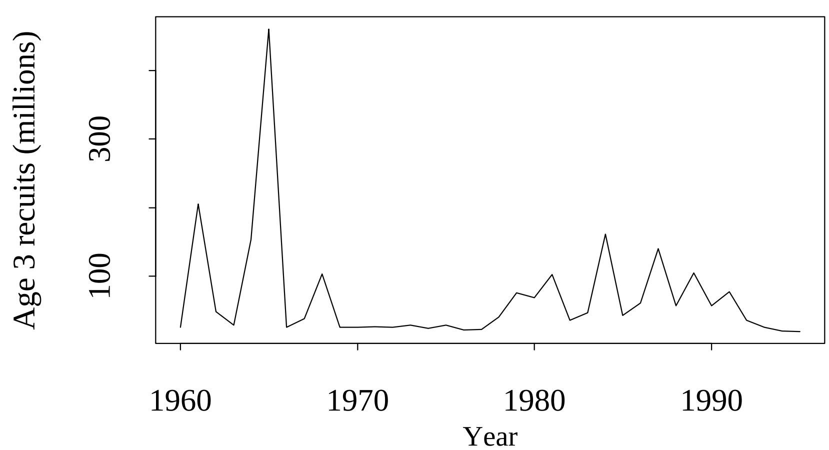


Figure 12. Estimated recruitment (age 3) of BSAI POP.

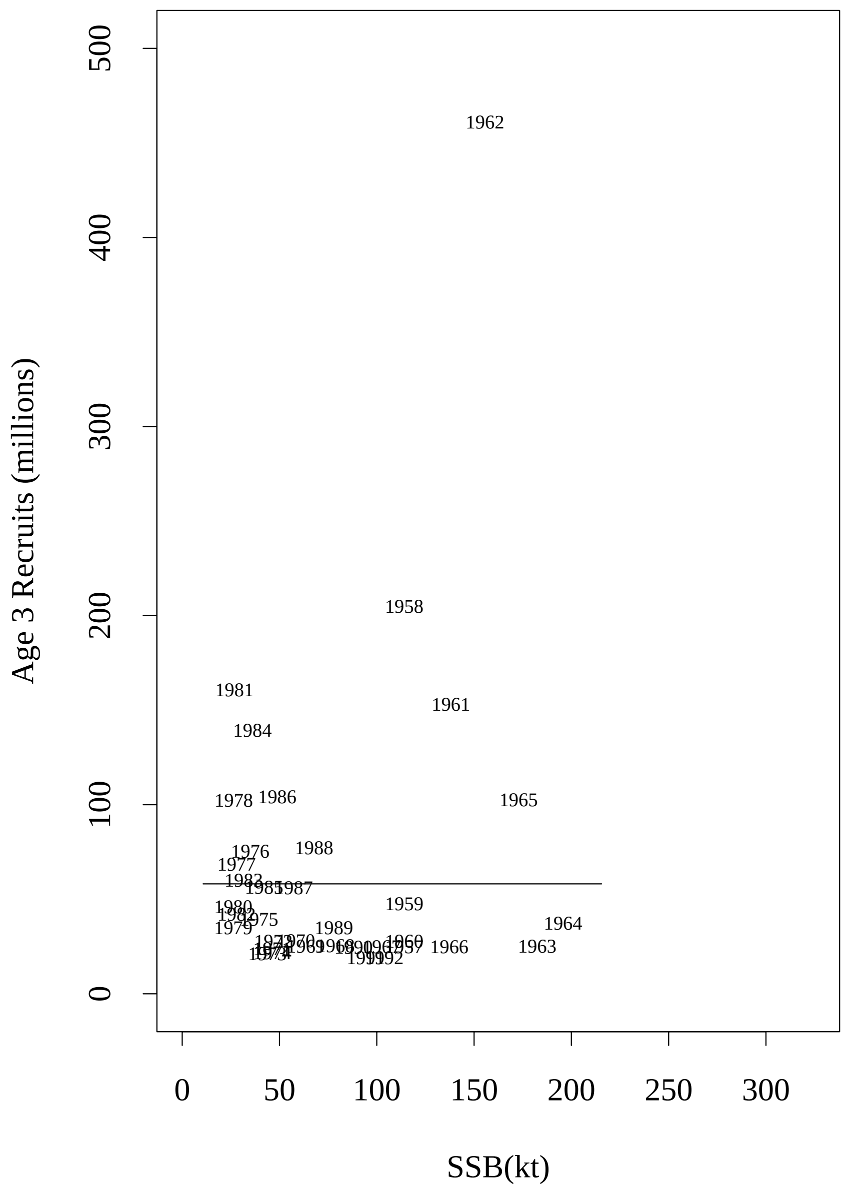


Figure 13. Scatterplot of BSAI POP spawner-recruit data; label is year class.